

In the Claims

This listing of claims will replace all prior versions and listings of claims in the application:

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1 1.<sup>v</sup> (Currently Amended) A method for generating digital filter  
2 coefficients for corresponding digital filters for tuning a hearing  
3 aid employing digital audio processing to enhance hearing ability  
4 comprising:

5 providing first digital data for a tolerance range for a  
6 target response curve representative of said enhanced hearing  
7 ability of sound level versus frequency;

8 providing second digital data representing an initial response  
9 curve of an initial hearing ability to be enhanced of sound level  
10 versus frequency;

11 comparing said first digital data to said second digital data  
12 and determining whether said initial response curve is within said  
13 tolerance range; and

14 if said initial response curve is not within said tolerance  
15 range, iteratively generating digital filter coefficients  
16 controlling center frequency, filter bandwidth and amplitude for a  
17 succession of additional digital audio filters, applying all  
18 currently generated digital audio filters to said second digital  
19 data to generate third digital data for a compensated response  
20 curve, and automatically optimizing the center frequency, amplitude  
21 and filter bandwidth of said currently generated digital audio  
22 filters until said compensated response curve is within said  
23 tolerance range or a predetermined limit on the number of digital  
24 audio filters has been reached, whichever occurs first.

1 2. (Original) A method according to Claim 1, wherein said step of  
2 iteratively generating digital audio filters is performed by  
3 iteratively generating second order filters.

1 3. (Original) The method of Claim 1 wherein said initial response  
2 curve is an audiogram.

1 4.<sup>y</sup> (Currently Amended) A method for generating a set of second  
2 order filter coefficients for corresponding digital filters to tune  
3 a hearing aid employing digital audio processing to enhance hearing  
4 ability comprising:

5 providing first digital data for a tolerance range for a  
6 target response curve representative of said enhanced hearing  
7 ability of sound level versus frequency;

8 providing second digital data representative of an initial  
9 response curve of an initial hearing ability to be enhanced of  
10 sound level versus frequency;

11 comparing said first digital data to said second digital data  
12 and determining whether said initial response curve is within said  
13 tolerance range; and

14 if said initial response curve is not within said tolerance  
15 range, generating a set of digital filter coefficients controlling  
16 center frequency, filter bandwidth and amplitude for a succession  
17 of additional digital audio filters to tune said hearing aid by  
18 performing the following optimizing steps iteratively,

19 digitally processing said second digital data to  
20 determine an  $n^{\text{th}}$  set of initial digital filter coefficients for  
21 an  $n^{\text{th}}$  digital filter for an  $n^{\text{th}}$  peak in said actual initial  
22 curve where said initial response curve is not within said  
23 tolerance range, including a center frequency, and an  
24 amplitude and a bandwidth for said peak, where  $n$  is the number  
25 of an iteration of said optimizing steps,

26 digitally generating digital filter coefficients  
27 controlling center frequency, filter bandwidth and amplitude  
28 for a compensating  $n^{\text{th}}$  digital filter from said  $n^{\text{th}}$  set of

29 initial parameters,  
30 applying said  $n^{\text{th}}$  digital filter to said second digital  
31 data and modifying said  $n^{\text{th}}$  set of initial digital filter  
32 coefficients to determine an  $n^{\text{th}}$  set of optimum parameters for  
33 said compensating  $n^{\text{th}}$  digital filter, to generate third digital  
34 data for an  $n^{\text{th}}$  interim compensated response curve of sound  
35 level versus frequency,  
36 processing said third digital data to determine whether  
37 said  $n^{\text{th}}$  interim compensated response curve is within said  
38 tolerance range,  
39 if said  $n^{\text{th}}$  interim compensated response curve is not  
40 within said tolerance range, performing another iteration of  
41 said optimizing steps until said interim compensated response  
42 curve is within said tolerance range or a predetermined limit  
43 on the number of digital filters has been reached, whichever  
44 occurs first.

1 5. (Previously Amended) A method of Claim 4, wherein said step of  
2 digitally generating a compensating  $n^{\text{th}}$  digital filter is performed  
3 by digitally generating a second order filter.

1 6. (Original) The method of Claim 4, wherein said initial  
2 response curve is an audiogram.

1 7.<sup>v</sup> (Currently Amended) A method for generating digital filter  
2 coefficients for corresponding digital filters for tuning a hearing  
3 aid employing digital audio processing to enhance hearing ability  
4 comprising:

5 providing first digital data for a tolerance range for a  
6 target response curve representative of said enhanced hearing  
7 ability of sound level versus frequency;

8 providing second digital data for an initial response curve of

9 said hearing ability to be enhanced of sound level versus  
10 frequency;

11 comparing said first digital data to said second digital data  
12 and determining whether said initial response curve is within said  
13 tolerance range; and

14 if said initial response curve is not within said tolerance  
15 range, generating a set digital filter coefficients controlling  
16 center frequency, filter bandwidth and amplitude for a succession  
17 of additional compensating digital audio filters by performing the  
18 following single filter optimizing steps iteratively,

19 digitally processing said second digital data to  
20 determine an  $n^{\text{th}}$  set of initial parameters for an  $n^{\text{th}}$  peak in  
21 said initial response curve where said initial response curve  
22 is not within said tolerance range, including a center  
23 frequency, an amplitude and a bandwidth for said peak, where  $n$   
24 is the number of an iteration of said optimizing steps,

25 digitally generating a compensating  $n^{\text{th}}$  digital filter  
26 from said  $n^{\text{th}}$  set of initial parameters,

27 applying said  $n^{\text{th}}$  digital filter to said second digital  
28 data and modifying said  $n^{\text{th}}$  set of initial filter coefficients  
29 to determine an  $n^{\text{th}}$  set of optimum parameters for said  $n^{\text{th}}$   
30 digital filter, to generate third digital data for an  $n^{\text{th}}$   
31 interim compensated response curve of sound level versus  
32 frequency;

33 if  $n > 1$ , performing the following joint filter optimizing  
34 steps iteratively and cyclically,

35 generating fourth digital data for interim computed  
36 response curves in which for each joint filter optimizing  
37 iteration one of said  $n$  filters is absent, and then performing  
38 said single filter optimization steps utilizing said fourth  
39 digital data to generate fifth digital data for an updated  
40 interim response curve,

41           digitally processing said fifth digital data to determine  
42 whether the most recent of said joint filter optimizing  
43 iterations has resulted in a change in said updated interim  
44 response curve greater than a predetermined amount of change,  
45 and if so continuing to perform said joint filter optimizing  
46 steps;

47           processing said fifth digital data to determine whether  
48 said  $n^{\text{th}}$  interim compensated response curve is within said  
49 tolerance range, and if not,

50           performing another iteration of the foregoing steps  
51 until said interim compensated response curve is within  
52 said tolerance range or a predetermined limit on the  
53 number of digital filters has been reached, whichever  
54 occurs first,

55 but if so, ceasing performance of further iterations.

1   8.   (Previously Amended) A method according to Claim 7, wherein  
2 said step of digitally generating a compensating  $n^{\text{th}}$  digital filter  
3 is performed by digitally generating a second-order filter.

1   9.   (Original) The method of Claim 8 wherein said initial response  
2 curve is an audiogram.

1   10. (Previously Amended) A method for generating digital filter  
2 coefficients for tuning a hearing aid employing digital audio  
3 processing to enhance hearing ability of an individual comprising:  
4       fitting said hearing aid to said individual;  
5       connecting said hearing aid to a source of audio digital  
6 signals;  
7       providing said individual with a device to generate indication  
8 signals at will;  
9       generating and providing a first series of audio digital

10 signals to said hearing aid, each digital signal in said first  
11 series of signals corresponding to an analog audio signal having a  
12 selected frequency and multiple power levels;

13 at said hearing aid converting each of said series of digital  
14 signals into said corresponding analog audio signal;

15 receiving said indication signal during said generation of a  
16 signal of a selected frequency indicative of said individual  
17 hearing said selected frequency;

18 providing a digital audio processing unit in said hearing aid  
19 for processing received audio digital signals corresponding to  
20 analog audio signals and providing processed audio digital data,  
21 including applying digital audio filters for tuning said hearing  
22 aid characterized by generating digital filter coefficients in  
23 algorithms applied to said received audio digital signals to effect  
24 said digital audio filters;

25 providing a digital computer connected to receive said first  
26 series of audio digital signals and said indication signals to  
27 generate digital data representative of said individual's hearing  
28 ability using said hearing aid without filters determined from said  
29 first series of digital signals, said computer programmed to  
30 determine said digital filter coefficients for digital filters for  
31 tuning said hearing aid and providing said coefficients to said  
32 digital audio processing unit in said hearing aid.

1 11.<sup>v</sup> (Currently Amended) A method according to Claim 10, wherein  
2 said digital computer is programmed to determine said digital  
3 filter coefficients by

4 providing second digital data for a tolerance range for a  
5 target response curve ability of representative of said  
6 individual's enhanced hearing ability of sound level versus  
7 frequency;

8 providing first digital data representative of an initial

9 response curve of said individual's hearing ability of sound level  
10 versus frequency;  
11 comparing said second digital data to said first digital data  
12 and determining whether said response curve is within said  
13 tolerance range; and  
14 if said response curve is not within said tolerance range,  
15 iteratively generating digital filter coefficients  
16 controlling center frequency, filter bandwidth and amplitude  
17 for a succession of additional digital audio filters,  
18 applying digital audio filters determined by said digital  
19 filter coefficients to said first digital data to generate  
20 third digital data for a compensated response curve, and  
21 automatically optimizing said digital filter coefficients  
22 by optimizing the center frequency, amplitude and filter  
23 bandwidth of said digital audio filters until said compensated  
24 response curve is within said tolerance range or a  
25 predetermined limit on the number of digital audio filters has  
26 been reached, whichever occurs first.

1 12. (Previously Amended) The method of Claim 11 wherein said  
2 computer receives said first series of signals and indication  
3 signals generated by said device to generate said first digital  
4 data.

1 13. (Original) The method of Claim 11 wherein said first digital  
2 data is an audiogram.

1 14. (Previously Amended) An apparatus for generating digital  
2 filter coefficients for tuning a hearing aid digital audio  
3 processing for use by an individual, comprising:  
4 a source of first audio digital data corresponding to analog  
5 audio signals having a selected frequency and multiple power

6 levels;

7 a digital audio processing unit in said hearing aid for  
8 processing said first audio digital data according to at least one  
9 digital filter having digital filter coefficients controlling  
10 filter center frequency, amplitude and filter bandwidth and  
11 providing processed audio digital data, including applying digital  
12 audio filters for tuning said hearing aid characterized by  
13 coefficients in algorithms applied to said first audio digital data  
14 to effect said digital audio filters;

15 a digital to analog converter receiving said processed digital  
16 data from said digital audio processing unit and converting said  
17 processed digital data into a corresponding analog audio signal;

18 a speaker receiving said analog audio signal from said digital  
19 to analog converter and producing corresponding sound to the  
20 individual;

21 a device for generating indication signals indicative of said  
22 individual receiving said sound; and

23 a digital computer connected to receive said first audio  
24 digital data and said indication signals, said digital computer  
25 programmed to determine said digital filter coefficients for  
26 digital filters for tuning said hearing aid and provide said  
27 coefficients to said digital audio processing unit.

1 15.<sup>v</sup> (Currently Amended) An apparatus according to Claim 14,  
2 wherein said digital computer is programmed to generate second  
3 digital data representative of said individual hearing ability when  
4 using said hearing aid without filters determined from said first  
5 audio digital data and said indication signals and to determine  
6 said coefficients by

7 providing third digital data for a tolerance range for a  
8 target response curve of enhanced hearing of sound level versus  
9 frequency;



10 providing said second digital data, wherein said second  
11 digital data represents an initial response curve of hearing  
12 ability of sound level versus frequency;

13 comparing said third digital data to said second digital data  
14 and determining whether said initial response curve is within said  
15 tolerance range; and

16 if said initial response curve is not within said tolerance  
17 range,

18 iteratively generating digital filter coefficients  
19 controlling center frequency, filter bandwidth and amplitude  
20 for a succession of additional digital audio filters,

21 applying digital audio filters determined by said digital  
22 filter coefficients to said second digital data to generate  
23 fourth digital data for a compensated response curve, and

24 automatically optimizing said digital filter coefficients  
25 by optimizing the center frequency, amplitude and filter  
26 bandwidth of said digital audio filters until said compensated  
27 response curve is within said tolerance range or a  
28 predetermined limit on the number of digital audio filters has  
29 been reached, whichever occurs first.

1 16.<sup>v</sup> (Currently Amended) A method for generating digital filters  
2 for tuning a hearing aid to enhance hearing ability, comprising:

3 providing first digital data for a tolerance range for a  
4 target response curve representative of said enhanced hearing  
5 ability of sound level versus frequency;

6 providing second digital data representing an initial response  
7 curve of an initial hearing ability to be enhanced of sound level  
8 versus frequency;

9 comparing said first digital data to said second digital data  
10 and determining whether said initial response curve is within said  
11 tolerance range; and

12 if said initial response curve is not within said tolerance  
13 range,  
14 iteratively generating digital filter coefficients  
15 controlling center frequency, filter bandwidth and amplitude  
16 for a succession of additional digital audio filters to  
17 compensate said initial response curve,  
18 applying said digital audio filters to digital signals  
19 representative of received sound to generate third digital  
20 data, converting said third digital data to an analog signal  
21 and providing said analog signal to a speaker in said hearing  
22 aid,  
23 generating fourth digital data representative of an  
24 enhanced response curve of hearing ability of sound level  
25 versus frequency;  
26 comparing said first digital data to said fourth digital  
27 data and determining whether said enhanced response curve is  
28 within said tolerance range; and  
29 automatically optimizing the center frequency, amplitude  
30 and filter bandwidth of said digital audio filters until said  
31 enhanced response curve is within said tolerance range or a  
32 predetermined limit on the number of digital audio filters has  
33 been reached, whichever occurs first.

1 17. (Original) A method according to Claim 16, wherein said step  
2 of iteratively generating digital audio filters is performed by  
3 iteratively generating second-order filters.

1 18. (Original) The method of Claim 16 wherein said initial  
2 response curve is an audiogram.

1 19. (Original) The method of Claim 18 wherein said enhanced  
2 response curve is an audiogram.

1 20. (Original) A method for generating total log-integral metric  
2 digital data for characterizing the perceived performance of a  
3 hearing aid, comprising the steps of:

4 providing first digital data for N samples for a desired  
5 response curve of acceptable hearing ability of sound level  
6 versus frequency;

7 providing second digital data representing N samples for an  
8 initial response curve of sound level versus frequency; and

9 generating total log-integral metric data according to the  
10 formula:

11 
$$M = \sum_{i=1}^{N-1} \log_{10} \left( \frac{f_{i+1}}{f_i} \right) \left[ \frac{|S(f_i)_{dB} - D(f_i)_{dB}| + |S(f_{i+1})_{dB} - D(f_{i+1})_{dB}|}{2} \right]$$

12 where:

13 M is the total log-integral metric,

14 f is the frequency,

15 D is the first digital data,

16 S is the second digital data, and

17 N is the number of samples of first digital data and of second  
18 digital data.

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